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A multi-criteria decision-making approach of transport intersection toward sustainable urban transport index

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ABSTRACT

Intersections are key causes of traffic problems from a traffic engineering perspective. To determine the options of intersection investment, this study proposes a new framework by performing multicriteria decision-making analysis (MCDA) to determine the manner by which an entire network is affected. A study utilizing comprehensive SAW, TOPSIS, VIKOR, and PROMETHEE techniques is performed and focuses on three main criteria. Additionally, nine subcriteria related to SUTI are considered. This new framework examines the effects of urban mobility levels, which promote effective intersection options. In this regard, MCDA serves as an efficient filter that focuses on the most effective alternatives of an entire network. This decision-making framework is a novel idea for intersections along new corridors, particularly in developing cities, where bypasses are crucial for addressing urban sprawl. A case study in Mukdahan, Thailand, shows that an urban growth rate of 1.856 % affects the effectiveness of intersection selection for road transportation.

1. Introduction

Based on a study focusing on areas of urban sprawl for urban transport engineering purposes, 48.7 % of people within a 4.3 billion population live in urban areas [1]. This represents the goal of Sustainable Development Goals (SDGs), which is consistent with the city prosperity index [2,3], and promotes urban mobility via the direct utilization of the sustainable urban transport index (SUTI).

A study that monitored Sustainability mobility in Asia-Pacific cities [4] indicates the following: A direct relationship is observed between land use and public transport. In developing countries, immigrants participate in urbanization [5], which causes traffic and transportation problems. Passenger travel behavior is a key criterion used to create effective policies in transport engineering. It has emerged at important local, regional, and global levels [6,7] and is consistent with goal no. 11 of the SDGs for sustainable cities and communities, which comprises policies for sustainable transport [8].

The 56 updated multicriteria decision-making analysis (MCDA) methods are an extensive set of methods characterized by their unique properties. The quality of recommendations decreases when the input is applied incorrectly, and the appropriate techniques differ in terms of the descriptors of the decision problem, the MCDA properties, and the verification and validation of the MCDA method [9]. Transport cases from 1985 to 2012 revealed that MCDA was employed in the field of transport, where the mobility management subcategory of the analytic hierarchy process (AHP)/ANP was primarily utilized. Hence, intersections that cause traffic problems in road networks must be examined [10–12]. An increase in traffic volume directly affects the capacity to accommodate traffic at intersections. By contrast, MCDA improvements in the fuzzy term showed advanced ideas, such as the cubic Fermatean Einstein fuzzy weighted geometric operator, triangular cubic fuzzy number, triangular cubic linguistic heuristic fuzzy, interval-valued bipolar neutrosophic fuzzy, Domination in bipolar fuzzy soft graphs, Cubic fuzzy Einstein aggregation, Weighted average rating (war) method for solving group decision making problem using triangular cubic fuzzy hybrid aggregation (tcfha) operator and trapezoidal cubic fuzzy Number [13–21], which are useful for future studies.

From 1982 to 2019, research pertaining to the MCDM, which was re-experienced using the AHP method, was executed in more than 60 % of the total road transport sector [22,23]. MCDM methods are primarily applied to evaluate transport options instead of transport policies or projects. The aim of this study is to present a novel framework for decision-making to achieve the most effective and suitable alternative selection. Specifically, a new decision-methodology framework that links transport intersection selection to the SUTI is proposed for addressing issues pertaining to transport travel behaviors. Additionally,

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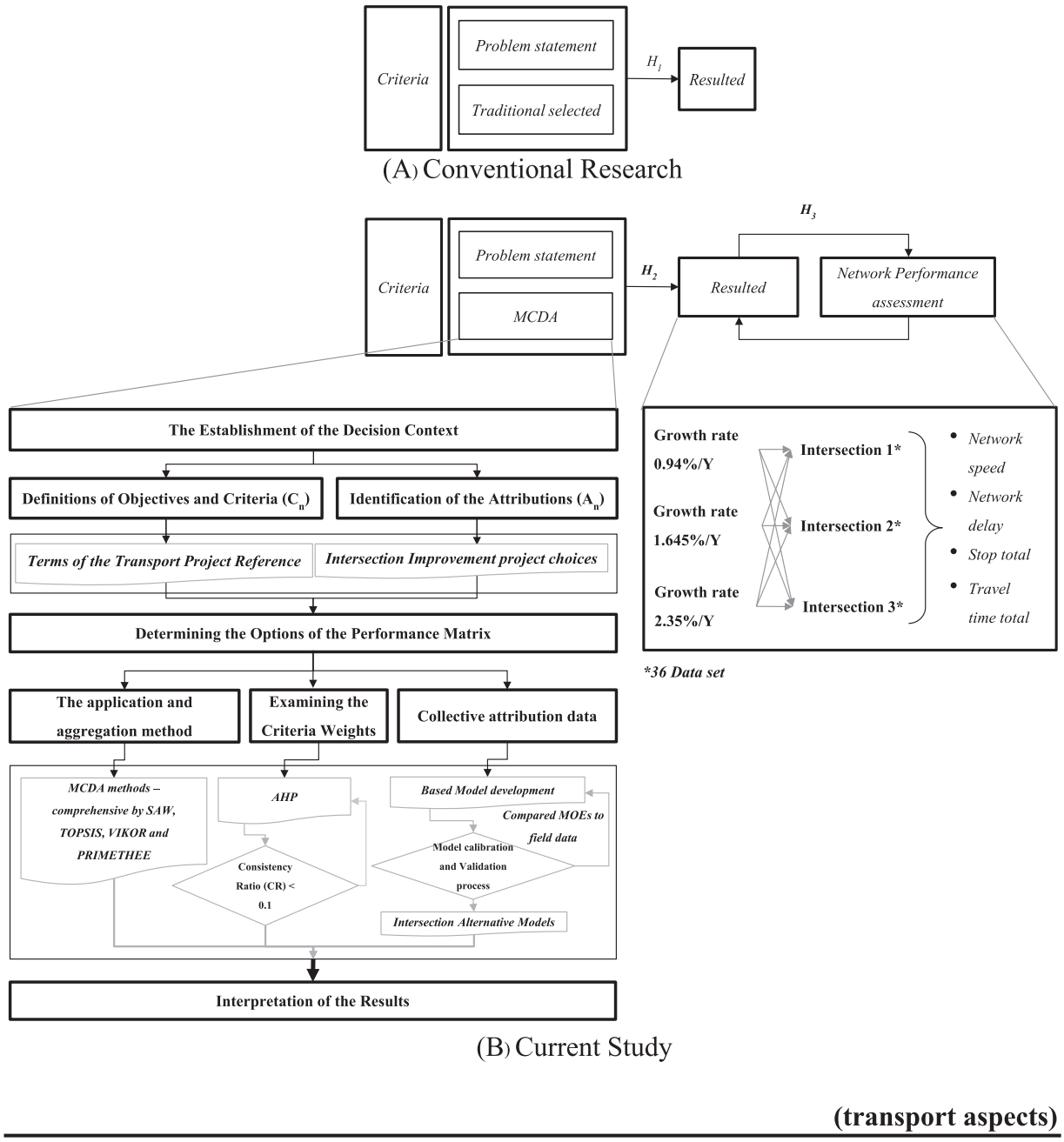

Fig. 1. Typical research procedure using MCDA.

the conventional study area for transport intersection selection is extended, and key considerations are presented to verify MCDA and urban growth.

2. Methods

The research procedure is shown in Fig. 1. The conventional selection method is based on cumulative survey data and decisions made using conventional techniques. This study presents a new framework that combines various MCDAs in the decision term; the effective result is represented, and the selection result is based on macro perspectives along the network.

2.1. Study case

Based on the identification of urban sprawl [24], both passenger transport demand and freight transport [25] affect developing countries [26–28]. In Southeast Asia, new urban designs are established that reflect compact cities and are in accordance with transport engineering, land usage, and urban transport mobility, as presented in Fig. 2.

The 2018–2023 report of the Department of Highway (DOH) of Thailand showed an annual increase of 1.91 % in vehicle registration, or an increase of 0.97 million vehicles per year [31], which corresponded to an average annual increase of 2.976 % [32]. In 2020, more than 1,300 cases of traffic accidents were recorded in Thailand. These accidents occurred in the straight and curved routes is more than 6.95 % of all types of accidents [33]. In 2022, the Ministry of Highways reported that the total number of intersections in Thailand exceeded 19,565 [34]. This

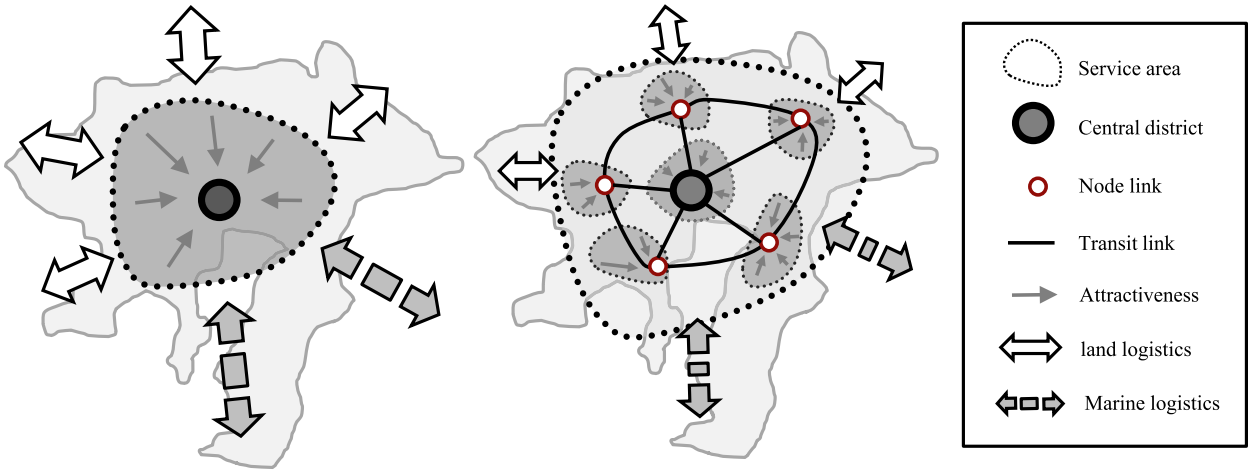

Fig. 2. Polycentric model: urban village version, Japan [29,30].

was based on the East–West Economic Corridor in the suburban area of Mukdahan Province, which was selected for its suburban growth. The new corridor (represented by Rural Highway No. 4040) crosses the following intersections on the southwest side: Highway 212 (Intersection-1), Highway 12 (Intersection-2), and Highway 212 (Intersection-3) on the Southwest side. Currently, traffic at intersections is controlled by traffic signals. The urban growth of Mukdahan, Thailand, utilizing the compact city-planning between 2013 and 2023 (see Fig. 3), [35].

2.2. Decision structure

Previously, 43 criteria within four dimensions [37] as well as nine parameters presented in a study pertaining to transport intersection selection were considered [38]. This study focuses on factors based on microsimulation results within three criteria: Traffic engineering, economics, and environmental impact. The subcriteria are listed in Table 1.

Network efficiency in terms of transport represents the comprehensive results between time and space [41] and is determined by mobility, accessibility, productivity, efficiency, utility, equity, reliability, waiting times, network structures, traffic demand, travel options, and travel costs. The scope of this study includes investigation into network efficiency within the dimension of transport engineering, based on the following four parameters: 1. Total travel time (s), 2. total stops (number of stops), 3. network delays (km/h), and 4. network speed (s/veh).

2.3. Development of traffic microsimulation model

2.3.1. Traffic microsimulation

A traffic microsimulation model was used to analyze the efficiency of traffic management at intersections. The efficiency indicators were obtained from a traffic simulation at the micro level. They were analyzed based on the AHP [42] as well as various previous cases [43,44]. Subsequently, they were used in an MCDA [45] to establish an effective assessment framework for intersection project alternatives.

Dowling et al. [46] performed a traffic microsimulation using car-following and lane-changing models and explained vehicle movement based on road conditions and utilities. These models are typically used in two- and three-dimensional forms in software packages such as PARAMICS, PTV VISSIM, and AIMSUN, which are commonly used to analyze complex traffic problems. Traffic microsimulation has been widely adopted for intersection analysis, which includes the effect of the number of pedestrians using crossings controlled by traffic signals, the evaluation of the corridor design based on results obtained from microsimulation via the AHP, and a technique for determining the order preference by comparing the similarity to the ideal solution from the MCDA. Zhu et al. (2020) & Fabianova et al. (2020) [47,48] created a model of an intersection controlled by traffic signals, which increased the flow at the intersection and reduced the average line length by 75 %. Zhu et al. [47] used a traffic microsimulation model that was established based on social force theory to examine the traffic-flow attributes of an intersection within a specific work zone [49]. These studies indicate that traffic microsimulation models are available for analyzing traffic at intersections.

Management and control approaches for traffic-intersection alternatives include traffic-signal control, roundabouts, overpasses, underpasses, and multilevel interchanges. Based on analysis and assessment results, both the Department of Highways and the Department of Rural Roads of Thailand should be responsible for traffic-intersection alternatives (which is the current situation in Thailand). In this regard, public requirement criteria [34,50,51] related to traffic volume, safety, environmental impact, and economic worthiness should be considered.

2.3.2. Data acquisition

Data obtained in the field were categorized into four groups: (1) geometric data (lane width, median width, aerial photos, etc.); (2) demand data (traffic volume and composition); (3) control data (traffic signals and intersection channelization); and (4) calibration data (mid-block count, spot speed, and average standstill distance). The details of the key survey data are presented in the following subsections.

2.3.2.1. Traffic volume. The traffic volume, which is related to the turning movement count, was surveyed during the peak hours of the morning (07.30–08.30 a.m.) and in the afternoon (15.30–16.30 p.m.) for calibration. Subsequently, these data were classified into the following three types of vehicles: Personal cars (PCs), heavy vehicles (HVs), and vehicles with more than four wheels, such as trucks and buses, including all types of trucks (except for four-wheel trucks and motorcycles). The results of the turning movement count survey administered during peak hours of the morning are shown in Fig. 4.

2.3.2.2. Spot speed. The spot speed is the speed at which a vehicle passes through a particular point on a road. A survey was conducted on three types of vehicles, i.e., Motorcycles, PCs, and HVs. The survey was conducted during a period free of unusual climate situations, incidences, or other factors that may interfere with traffic flow [52]. This study was classified into two categories of spot speeds, i.e., free-flow and turning speeds. The free-flow speed was measured using a radar speed gun, whereas the turning speed was measured using a stopwatch. The appropriate sample size for data acquisition in speed studies should include at least 50 vehicles, or more commonly, 100 vehicles [53]. In this study, the desired speed distribution for each vehicle type was

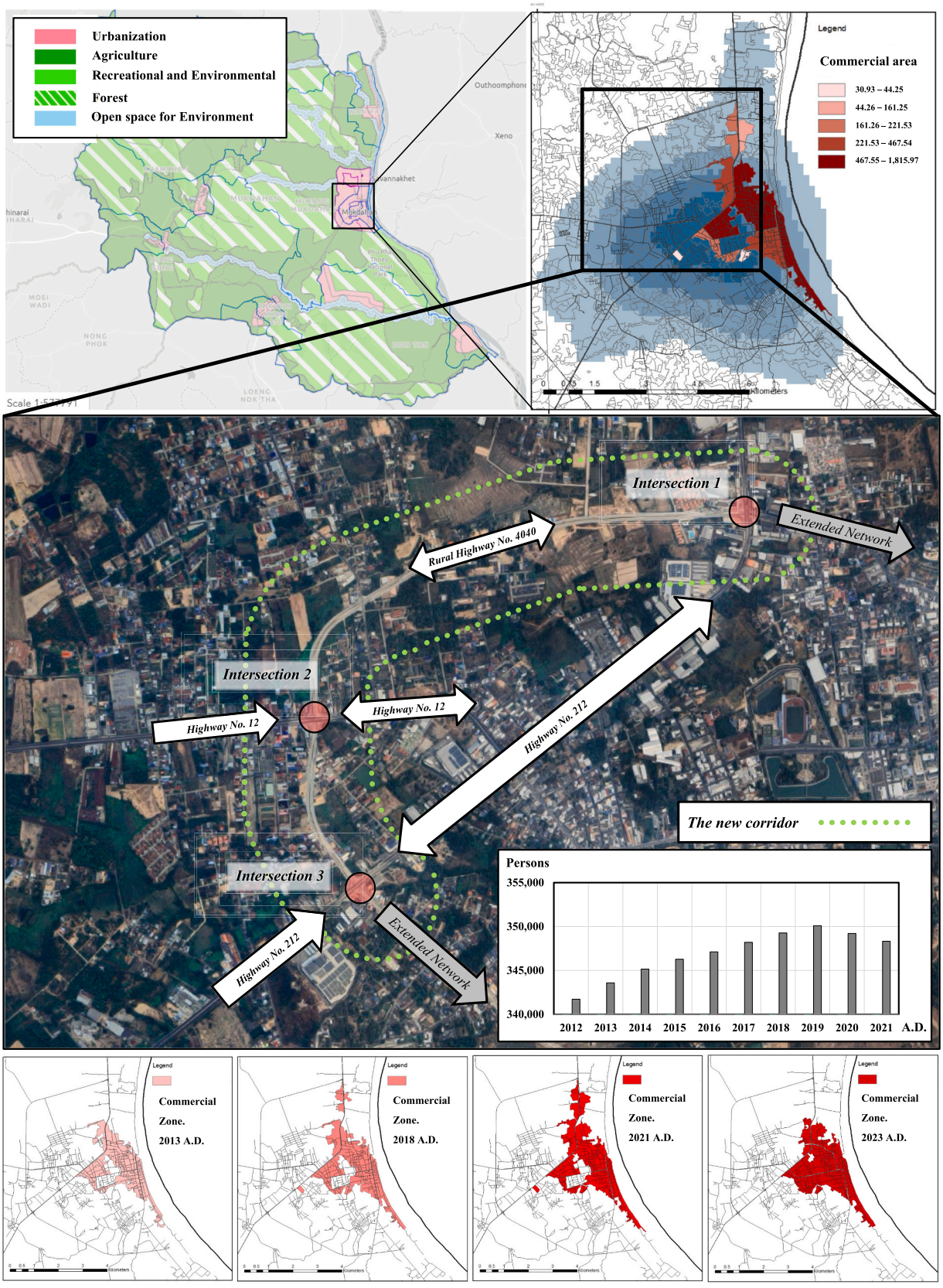

Fig. 3. Land use and commercial area of new corridor, i.e., Bypass Road, in Mukdahan, Thailand [35], population demographics for Mukdahan, Thailand, from 2012 to 2021 [36], and urban growth of Mukdahan, Thailand, from 2013 to 2023 [35].

Table 1
Criteria and parameters for selecting intersections based on transport engineering and sustainable urban mobility index (SUTI).

No.	Principle Criteria	Transport Engineering for Selecting Intersections (Units)	Literature			Sustainable Urban Mobility Index (SUTI)
			Rodrigo Rodrigues da Silva [37]	SPTI-LATAM. Alexandra Velasco and Regine Gerike [39]	Andressa Canal, et al. [40]	
1	**Engineering**	N.A.	N.A.	N.A.	N.A.	The extent to which transport plans include public transport, intermodal facilities, and infrastructure for active modes (0–16 scale)
2		N.A.	• Modal split	Paratransit mode share (%)		Modal share of active and public transport in commuting (Trips/ mode share)
3		• Average travel time (s) • Average vehicle delay (s/veh) • Average queue length (m) • Average stops (Number of stop)	• Congestion and traffic levels	Average trip time (min) Average speed (km/h)	• Transit average speed • Average traffic speed • Traffic jams • Traffic accidents	Convenient access to public transport services (Percentage of the population)
4		N.A.	N.A.	N.A.	N.A.	Public transport quality and reliability (Percentage of satisfaction)
5		N.A.	N.A.	N.A.	N.A.	Traffic fatalities per 100,000 inhabitants (Number of fatalities)
6	**Economics**	• Fuel consumption (L) • Vehicle hour travel, calculated from values of "all vehicles × all travel time" obtained from results of model (veh-h)	• Fossil fuel consumption • Energy consumption	• Frequency (veh/hour) • Fuel/oil and energy consumption (MJ/pkm) • Recovery of annual costs ($USD passenger revenues/total operating costs in $USD)	• Fuel consumption • Vertical equity (income)	Affordability – travel costs as part of income (Percentage of income)
7			N.A.		N.A.	Operational costs of the public transport system (Cost recovery ratio)
8		N.A.	• Municipal spending on transportation investment	• Users' costs ($USD/trip)	Investments in transport systems	Investments in public transport systems (Percentages of total investments)
9	**Environmental**	• CO emissions (g)	• Noise pollution	• CO_2 emissions (g/pkm)	CO emissions	Air quality (PM 10) (μg/m^3)
10	**Impact**	• NOx emissions NOx (g) • Volatile organic compound (VOC) emissions (g)	• Fossil-fuel consumption • Energy consumption	• PM10 emissions (g/pkm) • NOx emissions (g/pkm) • CO emissions (g/pkm)	CO_2 emissions	Greenhouse gas emissions from transport (CO_2 Eq. tons/capita/ year)

created in VISSIM using data from the field survey. This involved defining the minimum, maximum, and distribution values in the form of percentile speed to create the speed distribution. Generally, setting only two points is considered sufficient to represent most speed distributions for drivers near the average value [54]. A summary of the spot speed data survey is shown in Table 2.

2.3.2.3. Average standstill distance. The VISSIM program was used to calibrate the main variables in the Wiedemann 74 model. The most sensitive variable was the average standstill distance (CCO parameter) [54]. Thus, the distance between two cars, which was measured from the back bumper of the front car to the front bumper of the car behind it, was prioritized in this study. Additionally, video footage from the side of the road was recorded, and data pertaining to the safe following distance between pairs of vehicles, specifically PCs, were extracted to capture the distance between two cars (Fig. 5). The average safe following distance was used as a representative value for all vehicles observed during that period, with at least 100 data samples obtained per intersection. An average standstill distance of 2.45 m was obtained.

2.3.3. Base model

A link created via a street network connection was adopted to construct the traffic microsimulation model. Subsequently, the free-flow speed was deployed for all types of considerations to execute the desired speed distribution by positioning the phasing and cycle length of the traffic signals. The simulation was conducted based on the stochastic principle [46], which exceeds the 95 % confidence level, as shown in **Eq. (1)**. Additionally, the simulations were performed 11 times, and the standard error of the mean (E) was calculated based on the standard deviation (S) and number of samples (n) [55].

$$E = \frac{s}{\sqrt{n}} \tag{1}$$

2.3.4. Calibration and validation

The parameters of some of the variables in the model were changed by calibrating and validating the model such that the simulation results would closely reflect the actual observations. In this study, traffic volume was used as a calibrating indicator to validate the model. Hence, the criteria for the microsimulation parameters were based on the Design Manual for Roads and Bridges [55], which accounted for GEH statistics, as shown in **Eq. (2)**. Here, M represents the hourly traffic volume from the traffic model and C represents the real-world hourly traffic count. A GEH value of less than 5.0 is regarded as favorable when comparing the modeled and observed hourly volumes. Thus, in this study, the GEH was computed to be 0.15–3.63.

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}} \tag{2}$$

2.4. Application of traffic microsimulation model

This research contributed to the creation of a forecasting model that can support the demand scenarios of transport for 2034. The executed

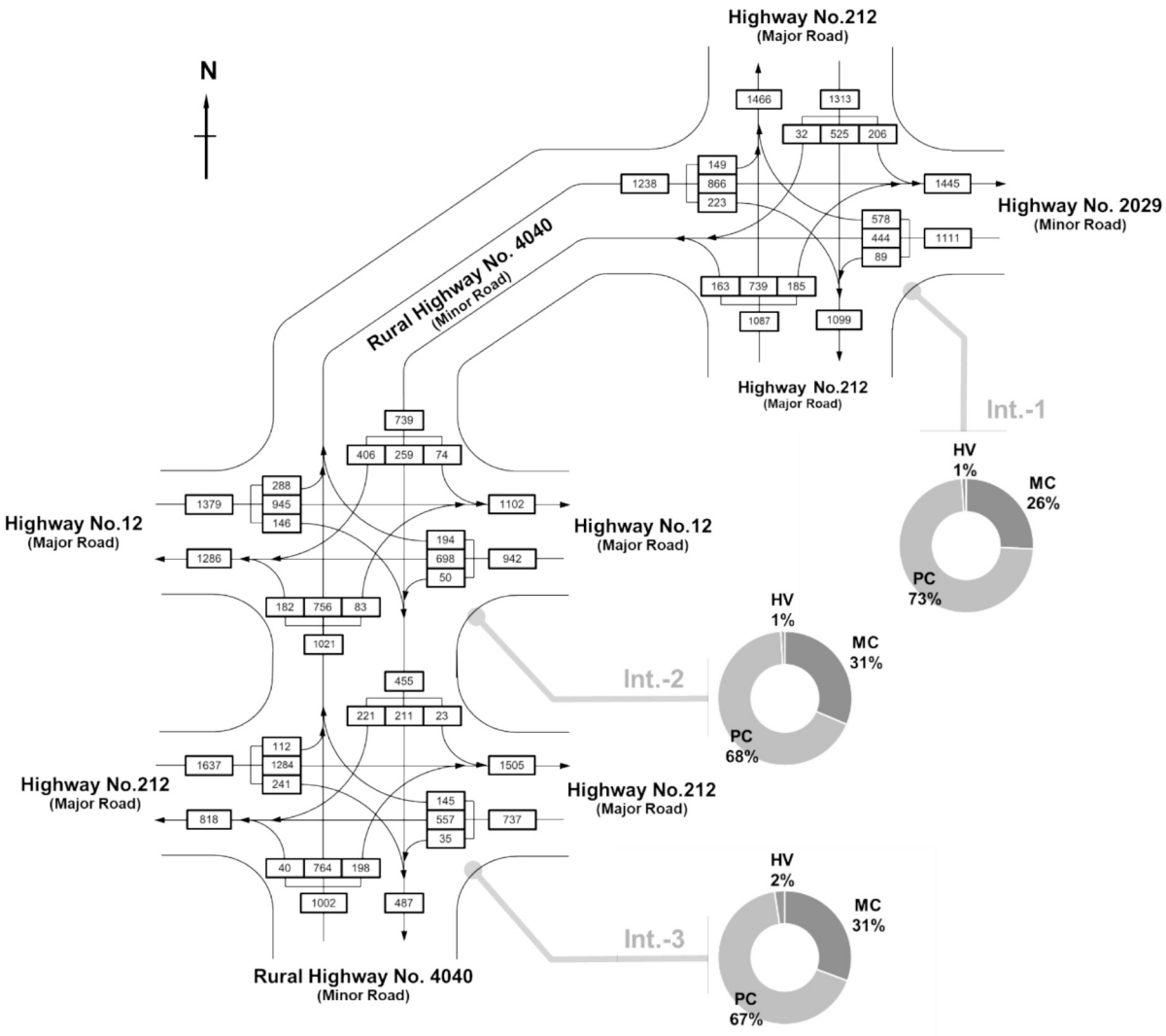

Fig. 4. Results of traffic volume survey (peak morning hours).

Table 2
Summary of spot-speed data survey.

Spot speed data	Free-flow speed (km/h)			Turning speed (km/h)		
	MC	PC	HV	MC	PC	HV
Minimum	25	52	39	9.8	11.6	9.9
15th percentile speed	46.5	66.1	50.1	10.1	13.6	10.9
50th percentile speed	58.2	77.5	58.7	10.8	15.5	12.4
85th percentile speed	74.9	86.3	68.4	13.1	17.1	13.7
Maximum	106	110	96	15.5	17.8	14.3
Average	59.3	77.4	59.1	11.5	15.3	12.2

growth rates were shown to be 0.940 %, 1.645 %, and 2.350 % per year, which were represented by low, moderate, and high traffic growths, respectively [56]. A traffic microsimulation model with seven intersection alternatives is shown in Fig. 6.

2.5. Calculation of Scores using SAW, TOPSIS, VIKOR, and PROMETHEE methods

The MCDA was combined with a decision tree and a set of descriptors [57,58] comprising the variables, weights of the criteria, and the weight

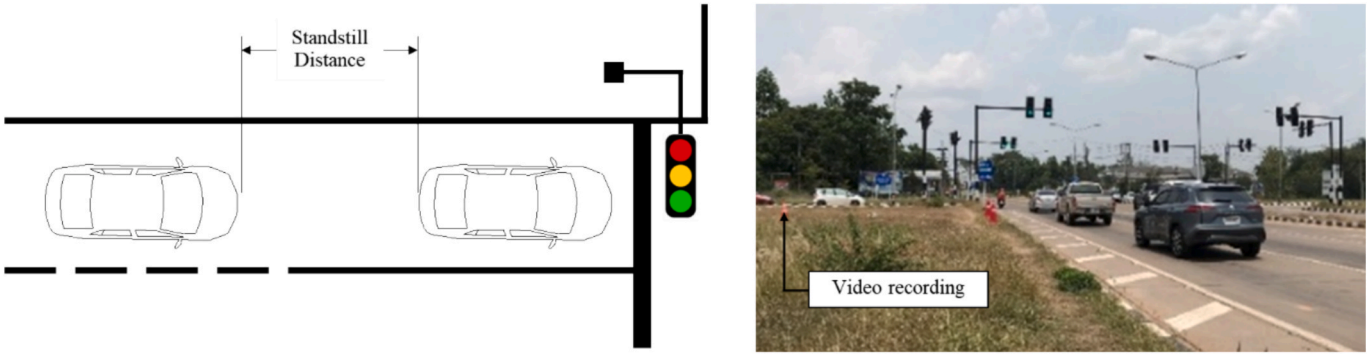

Fig. 5. Survey of average standstill distance.

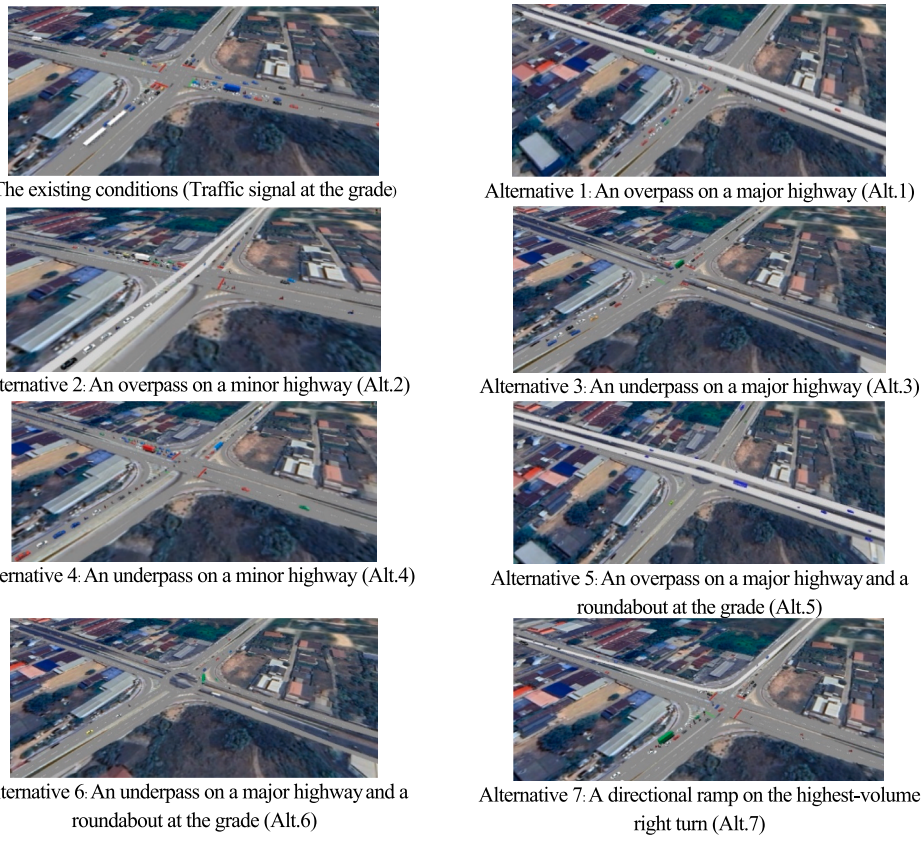
The existing conditions (Traffic signal at the grade)
Alternative 1: An overpass on a major highway (Alt.1)
Alternative 2: An overpass on a minor highway (Alt.2)
Alternative 3: An underpass on a major highway (Alt.3)
Alternative 4: An underpass on a minor highway (Alt.4)
Alternative 5: An overpass on a major highway and a roundabout at the grade (Alt.5)
Alternative 6: An underpass on a major highway and a roundabout at the grade (Alt.6)
Alternative 7: A directional ramp on the highest-volume right turn (Alt.7)

Fig. 6. Microsimulation and alternative models.

Table 3
Experiences and applications of Multicriteria decision analysis (MCDA).

Author (Year)	Techniques	Case study	
		Miscellaneous	Transport
Moureen Asaad et.al., 2024 [62]	AHP	Green neighborhood	
Bruno Estanqueira Pinho et.al., 2024 [63]	AHP	Nuclear fuel management strategy	
Sahand Hosouli and Rania Asma Hassani. [64]	Fuzzy Analytic Hierarchy Process (FAHP)	Solar plant location selection	
Asli Abdulvahitoglu and Mustafa Kilic., 2022 [65]	AHP-TOPSIS	Oilseed for biodiesel production	
Aliya Fahmi., 2024 [66]	Fuzzy TOPSIS technique and entropy	Natural gas	N.A.
Hasan Alper Kaya. et.al., 2024 [67]	Fuzzy AHP and TOPSIS	Coastal protection structures	
Reza Abdullah et.al., 2024 [68]	AHP, SAW, WASPAS, TOPSIS, EDAS, MOORA	Transit-oriented development (TOD)	
Filippo Accordino et.al., 2024[69]	TOPSIS	Linking urban railways, people, and places	
Alemdar et al., 2021 [38]	AHP and TOPSIS	Evaluation of intersection performances	
H. Poorzahedy, A. Rezaei, 2013 [70]	SAW and TOPSIS	Light rail transit network choices	
Ghazi Magableh et al., 2022 [71]	TOPSIS and PSI	Traffic solutions	
Jahromi et al., 2012 [72]	DALY weights and SIR Method, SIR-TOPSIS	Environmentally sustainable transport	
Vicente Martínez-Maldonado. et.al., 2023 [73]	PROMETHEE	Mass transit systems' route	Transport
Svetla Dimitrova Stoilova, 2019 [74]	WASPAS, VIKOR, and PROMETHEE	Railway transport	
Claudia Nodari et al., 2022 [75]	Fuzzy Analytic Hierarchy Process	Urban road networks: feasibility index	
Melih Yucesan et.al., 2024 [76]	MULTIMOORA	Sustainable urban transport index	
Umair Hasan et al., 2024 [77]	TOPSIS	Sustainable road transport systems	
Jorge Curiel-Esparza et al., 2016 [78]	VIKOR methods	Prioritization of sustainable mobility	
Żak, 2015 [79]	ELECTRE III/IV methods	Urban transportation projects	
Anjali Awasthi, 2018 [80]	Fuzzy VIKOR and TOPSIS	Evaluation of urban mobility	Transport (sustainable urban transport index)
Maja Kiba Janiak and Jacek Żak, 2014 [81]	AHP and Electre III/IV methods	Public tram system	

Table 4
Comparison of SAW, TOPSIS, VIKOR, and PROMETHEE methods.

Decision Structure		MCDA techniques			
		SAW	TOPSIS	VIKOR	PROMETHEE
Objectives and criteria (C_n)	Criteria	√	√	√	√
	Subcriteria	√	√	√	√
	Weight (AHP)	√	√	√	√
Collective data	Micro simulation	√	√	√	√
	Normalization	$R_{ij} = [x_{ij} - \max x_{ij}] / [\max x_{ij} - \min x_{ij}]$, (while i = 1, 2, …, n, j = 1, 2, …,m)			
Application of aggregation method	Formula	• $R_{ij} = x_{ij} / x_j$ *, if the j^{th} criteria is a benefit criter-ion, and • $R_{ij} = x_j - / x_{ij}$, if the j^{th} is the cost criter-ion	• R, $r_{ij} = x_{ij}$ / sq root (sum, i = … m of $x_{ij}2$) • Si* = Sq root (sum of squares for j = 1 ….., n) of ($V_{ij} - V_j$*) • Si- = Sq root (sum of squares for j = 1 ……., n) of ($V_{ij} - V_j$-) • (Ci*, i =,……., m) as $C_i^* = S_i$- / (S_i* + S_i-)	$L_{p,j} = \{\sum_{i=1}^{n}[w_i \left(f_i^* - f_{ij}\right) / (f_i^* - f_i^-)]^p\}^{1/p}$, 1 ≤ p ≤ ∞; j = 1,2, ……., j $S_j = L_{1,j} = \sum_{i=1}^{n} w_i \left(f_i^* - f_{ij}\right) / (f_i^* - f_i^-) R_j = L_{\infty,j} = max_j[\sum_{i=1}^{n} w_i \left(f_i^* - f_{ij}\right) / (f_i^* - f_i^-)]$ • $Q_j = v\,(S_j - S^*) / (S^- - S^*) + (1 - v)\,(R_j - R^*) / (R^- - R^*)$ • while v is introduced as the strategy weight of S_j and R_j	• P_j (i, i ‘) = 0 if $R_{i\,j}$ $R_{i\,'\,j}$ φ+(i)=1n-1i’=1nπ i’,i, i’ ≠iφ-(i)=1n-1i’=1nπ i’,i, i’ ≠iπ(i, i_) =(j=1mWj x Pj ((i, i ’)) / $\sum_{j=1}^{m} wj$ • P_j (i, i ‘) = ($R_{i\,j}$ − $R_{i\,'\,j}$) if $R_{i\,j}$ $R_{i\,'\,j}$ • ϕ+(i) = ϕ+(i) − ϕ−(i)
	Compared Best / Worst	×	√	√	√
	Compared best by attribution	×	×	√	√
	Pairwise comparison	×	×	×	√
Attribution Prioritization		Alt.1, Alt.2, …. Alt.7, According to Fig. 6 √			

Table 5
Weight priorities of indicators for decision-making on intersection model AHP to ANP.

Main criteria	Weight priorities of main criteria (1)	Subcriteria	Weight priorities of subcriteria (2)	Weights (1) × (2)
Engineering	0.526	Average travel time	0.2589	0.1362
		Average vehicle delay	0.3427	0.1803
		Average queue length	0.1524	0.0802
		Average stops	0.2281	0.1200
Economics	0.229	Fuel consumption	0.6388	0.1463
		Vehicle hour travel	0.5331	0.1221
Environ-mental Impact	0.245	CO emissions	0.2444	0.0599
		NOx emissions	0.3163	0.0775
		VOC emissions	0.3159	0.0774
Total	1.000	Total		1.000

* Consistency ratio (C.R.) analysis < 0.10.

variations. Previously, Watróbski [58] addressed the consistency among the SAW, TOPSIS [60], VIKOR, and PROMETHEE methods [59,61], which were used in this study. The framework of this study was extended to explain the effect of decision weights on other emerging alternatives [57]. The results suggest an approach for prioritizing and selecting a simplified intersection model based on data acquisition via a simulation model and decision-making through actual practice. Moreover, the MCDA method was verified and validated using comparative MCDA techniques, as shown in Table 3. Since 2012, MCDA techniques have been used continuously to determine the specificity of transport related to various issues, as shown in the example in Table 4.

3. Results and discussions

3.1. Results of AHP

By interviewing decision-makers and professionals, the pair weights for each hierarchy level were obtained, which were then compared to determine the importance of each decision component at each level [82,83]. The weight criteria were determined by interviewing 24 experts, which comprised 8 traffic engineering experts, 8 economists, and 8 environmental impact experts, all of whom were engaged in decision-making at a high level. The details of the weight priorities assigned by the experts are listed in Table 5.

3.2. Results of efficiency indicator Analyses and MCDA

This section discusses the use of analytical outcomes derived from PTV VISSIM for the different subcriteria based on which the simulation outcomes of the efficiency indicators were exported, as shown in Figs. 7–9.

The MCDA aspects revealed a comprehensive visualization regarding decisions pertaining to the nine indicator variables within three aspects. First, the four best scenarios, which represented the network assessment more effectively than the baseline (traffic-signal control) and filled the gap for Hypothesis 2 (H2′s answers), were as follows:

- Scenario 1: Alt.3 at Int.-1, Alt.3 at Int.-2, and Alt.6 at Int.-3
- Scenario 2: Alt.3 at Int.-1, Alt.3 at Int.-2, and Alt.3 at Int.-3
- Scenario 3: Alt.4 at Int.-1, Alt.3 at Int.-2, and Alt.3 at Int.-3
- Scenario 4: Alt.4 at Int.-1, Alt.3 at Int.-2, and Alt.6 at Int.-3

This analysis revealed that the evidence clearly shaped the possibility of the most effective alternatives, as shown in Table 6.

As mentioned above, Hypothesis 3 (H3) was supported through the network assessment. Based on the SUTI [84], this study focuses on four parameters, i.e., the network speed, network delays, total stops, and total travel time. With regard to the 0.940 growth rate, Scenario 3 was determined to be the most effective. Moreover, the result showed that when the growth rate increased up to 2.350 %, the intersection options

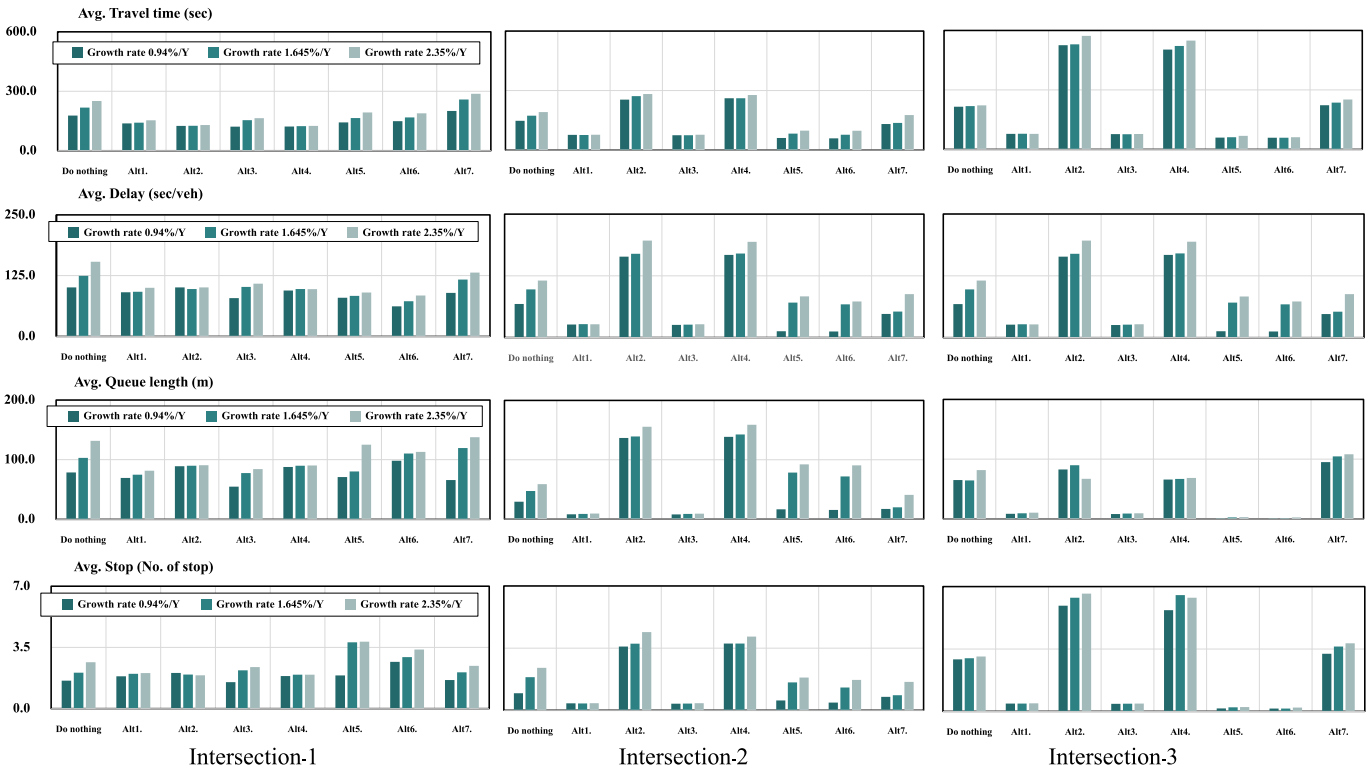

Fig. 7. Outcomes of PTV VISSIM simulation with engineering aspect within four subcriteria.

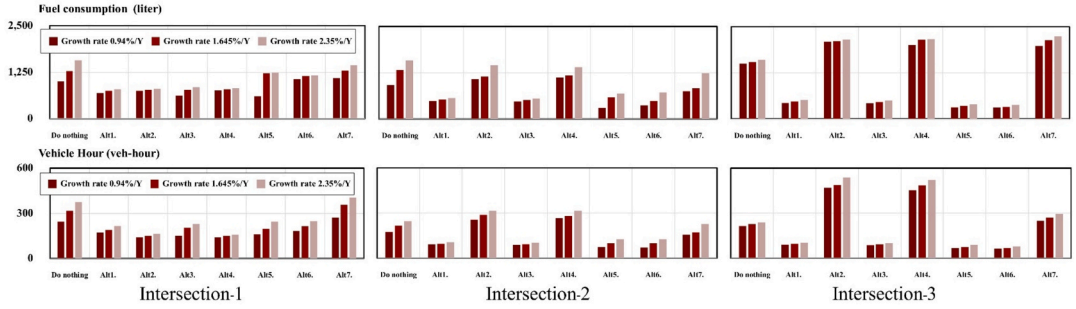

Fig. 8. Outcomes of PTV VISSIM simulation with economics aspect within two subcriteria.

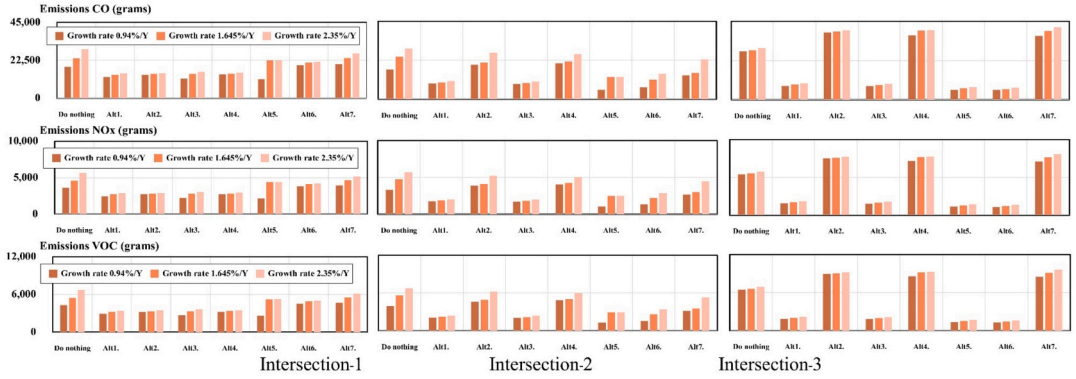

Fig. 9. Outcomes of PTV VISSIM simulation with environmental impact aspect within three subcriteria.

Table 6
Prioritization results based on multiple criteria decision-making analysis with seven attributions.

MDCA	Alternatives	Growth rate 0.940 %/Y			Growth rate 1.645 %/Y			Growth rate 2.350 %/Y		
		Int.-1	Int.-2	Int.-3	Int.-1	Int.-2	Int.-3	Int.-1	Int.-2	Int 3
SAW	Existing conditions	0.878	0.574	0.574	0.894	0.728	0.559	0.933	0.750	0.564
	Alt.1	0.698	0.286	0.153	0.596	0.268	0.156	0.550	0.248	0.157
	Alt.2	0.741	0.966	0.983	0.597	0.948	0.981	0.527	0.968	0.954
	Alt.3	0.609	0.277	0.149	0.636	0.260	0.152	0.592	0.244	0.151
	Alt.4	0.721	1.000	0.944	0.599	0.951	0.963	0.523	0.948	0.940
	Alt.5	0.654	0.203	0.093	0.790	0.429	0.104	0.746	0.427	0.110
	Alt.6	0.844	0.219	0.091	0.752	0.387	0.095	0.703	0.430	0.103
	Alt.7	0.907	0.466	0.706	0.935	0.459	0.730	0.899	0.601	0.735
TOPSIS	Existing conditions	0.180	0.752	0.752	0.316	0.280	0.506	0.062	0.234	0.513
	Alt.1	0.723	0.500	0.500	0.948	0.999	0.994	0.968	0.999	0.995
	Alt.2	0.557	0.484	0.485	0.990	0.015	0.001	0.980	0.005	0.009
	Alt.3	0.938	0.496	0.496	0.884	0.999	0.995	0.914	0.999	0.996
	Alt.4	0.650	0.427	0.427	0.989	0.011	0.007	0.987	0.010	0.009
	Alt.5	0.8741	0.488	0.488	0.694	0.912	0.999	0.572	0.899	0.999
	Alt.6	0.455	0.894	0.895	0.682	0.944	1.000	0.708	0.908	1.000
	Alt.7	0.169	0.499	0.499	0.238	0.853	0.257	0.128	0.530	0.252
VIKOR	Existing conditions	0.954	0.543	0.543	0.744	0.767	0.534	1.000	0.773	0.538
	Alt.1	0.426	0.136	0.078	0.501	0.015	0.075	0.052	0.009	0.069
	Alt.2	0.731	0.966	0.981	0.341	0.995	1.000	0.037	1.000	1.000
	Alt.3	0.000	0.124	0.074	0.584	0.000	0.071	0.179	0.000	0.062
	Alt.4	0.548	1.000	0.978	0.325	1.000	0.977	0.000	0.979	0.983
	Alt.5	0.098	0.000	0.003	0.070	0.264	0.011	0.565	0.284	0.012
	Alt.6	0.670	0.030	0.000	0.248	0.219	0.000	0.413	0.258	0.000
	Alt.7	0.833	0.385	0.728	1.000	0.312	0.765	0.799	0.533	0.781
PROMETHEE	Existing conditions	2.242	1.919	2.202	2.585	2.443	2.132	3.160	2.231	2.201
	Alt.1	−1.038	−1.541	−1.880	−1.835	−2.331	−1.880	−1.805	−2.517	−1.897
	Alt.2	−0.202	1.792	1.719	−0.958	1.510	1.731	−1.253	1.472	1.717
	Alt.3	−2.712	−2.460	−2.771	−2.144	−3.200	−2.774	−2.092	−3.263	−2.807
	Alt.4	−0.612	1.542	1.404	−1.244	1.265	1.422	−1.617	1.160	1.440
	Alt.5	−1.864	−2.544	−2.757	−0.767	−1.555	−2.701	−0.846	−1.603	−2.705
	Alt.6	1.466	−0.482	−0.849	1.270	0.264	−0.848	1.089	0.441	−0.888
	Alt.7	2.719	1.774	2.931	3.094	1.605	2.917	3.365	2.078	2.938

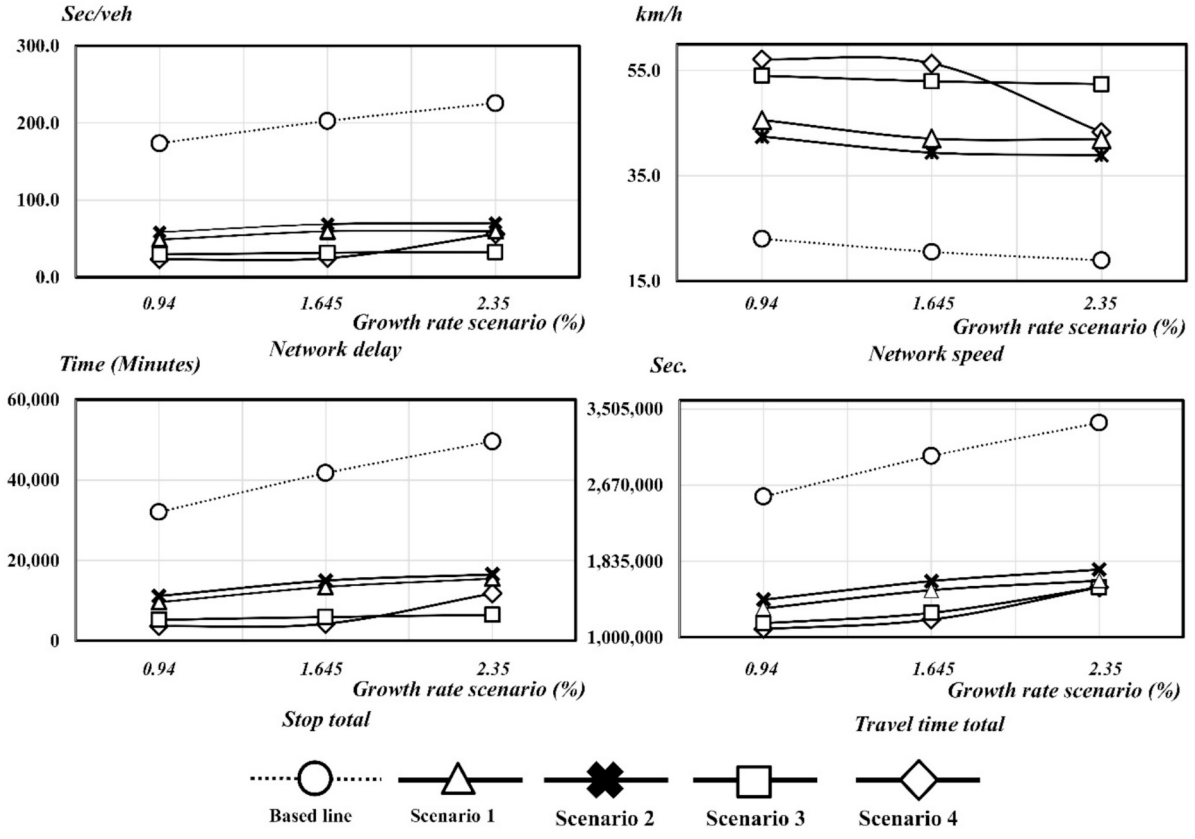

Fig. 10. Comparison of network assessment based on four scenarios.

were changed to Scenario 4, as shown in Fig. 10.

4. Conclusion

Economic growth increases the demand for urban transport mobility and directly affects travel behavior. Although the public mass transit system is a fully completed concept of urban and transport design, developing cities have been affected by issues related to new corridor development. Based on the urban sprawl, urban planning, which is related to creating effective intersection projects, is a crucial area of Transport Engineering study that involves selecting the appropriate investments in transportation projects. The link between the global achievement indicators, such as the SUTI, to local transport behavioral indicators is represented. This represents the frontier of combining the novel MCDA framework with transport microsimulation, which provides extended knowledge regarding the selection of transport intersections when considering an entire network based on the SUTI. Hence, by excluding the transport indicator for each intersection, measurements for the entire network, which constitute the new corridor development, were considered. MCDA methods have been primarily applied to evaluate transport options instead of to determine transport policies or projects. In addition, the parallel between optimization and multicriteria decision analysis is confronting and combining in the frontier Engineering field [85]. This study demonstrated the effective framework of MCDA for intersection selection and presented the optimal network assessment to address issues in transport engineering. The most effective options and the limitations of the options were revealed. Additionally, an urban growth rate of 1.856 % was shown to be significant for suburban areas in developing countries.

Ethical Approval

The study was approved by the Human Research Ethics Committee for Research Involving Human Subjects at the Rajamangala University of Technology, Isan, Thailand (HEC-02-66-022).

CRediT authorship contribution statement

Wantana Prapaporn: Writing – review & editing, Writing – original draft, Visualization, Supervision. **Wuttikrai Chaipanha:** Writing – original draft, Validation, Software, Methodology, Formal analysis, Conceptualization. **Patiphan Kaewwichian:** Validation, Project administration, Funding acquisition, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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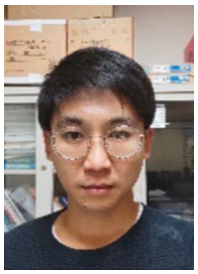

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